RADIATION SOURCE FOR ENDOVASCULAR RADIATION TREATMENT

FIELD OF THE INVENTION

[0001] The present invention relates to a radiation source for use in endovascular radiation treatment which radiation source comprises radiation emitting elements and is suitable for being delivered in a catheter to the selected site to be treated within the vascular system of a patient. The invention further relates to an apparatus for vascular radiation treatment using said radiation source as well as a method of treatment.

BACKGROUND OF THE INVENTION

[0002] Endovascular radiation treatment is the todays method of choice to prevent formation of scar tissue in a blood vessel which has been injured in various ways, for example, as trauma from surgical or diagnostic procedures. One area of the vascular system of particular concerns with respect to such injury is coronary arteries that are subjected to procedures for removing or reducing blockages due to plaques within the arteries. Partial and even complete blockage of the coronary arteries by the formation of an arteriosclerotic plaque is a well known and serious medical problem. Such blockages may be treated using arterectomy devices which mechanically remove the plaque, hot or cold lasers which vaporize the plaque, stents which hold the artery open and other devices and procedures well known in the art. The most common of them is the percutaneous transluminal coronary angioplasty, more commonly referred to as balloon angioplasty.

[0003] In this procedure a catheter having an inflatable balloon at its distal end is introduced into the coronary artery, the uninflated balloon is positioned at a stenotic site and the balloon is inflated. Inflation of the balloon disrupts and flattens the plaque against the arterial wall and stretches the arterial wall, resulting in enlargement of the intraluminal passageway and increased bloodflow. After such extension, the balloon is deflated and the balloon catheter removed.

[0004] Long term success of balloon angioplasty procedures is largly limited due to restenosis or re-closing of the intraluminal passageway through the artery by formation of scar tissue. Restenosis is experienced in approximately 30 to 50% of the patients within six months after balloon angioplasty. Apparently restenosis is to a significant extend a natural healing response to the vessel injury caused by inflation of the angioplasty balloon.

[0005] Injury of a vessel typically initiates the bodies own natural repair and healing process. During the healing process, fibrin and plathelets rapidly accumulate in the endothelium and vascular smooth muscle cells proliferate and migrate into the intima. The formation of scar tissue by smooth muscle proliferation (hyperplasia) is believed to be a major contributor to restenosis following balloon angioplasty of the coronary artery.

[0006] Prior attempts to inhibit restenosis have included the use of various light therapies, chemotherapeutical agents, stents, arterectomy devices, hot and cold lasers and so on. The most promising approach to inhibit restenosis is the use of radiation therapy, i.e. the exposure of the restenotic site to ionizing or radioactive radiation.

[0007] Although radiation therapy in general has been applied advantageously, the devices available for delivery of radiation sources and the radiation sources themselves have certain drawbacks which limit their usefulness. Typically, the devices include a catheter, which is directed by way of a guide wire inserted therein to the site of treatment. The catheter is then used to internally direct the radiation source to the site of treatment and to retract the same after a predetermined treatment time.

[0008] One typical problem encountered with the catheter and/or the radiation source is related to stiffness of the source which is directly proportional to its length. Therefore, to allow the radiation source to travel along the bends of a vessel, typically shorter sources are used and the so-called "stepping treatment" is applied to achieve radiation treatment of the entire site. Since, however, very exact positioning is not possible in a constantly moving vessel such as coronary artery,

long sources are desirable which allow for one-step treatment of the stenotic site in its entire length.

Description of the Related Art

[0009] For example, US-A-5,833,593 discloses a source wire which is modified at its treatment end to receive a radioactive element. A plug seals the unmodified section of the source from the lumen of the modified segment which contains the radioactive element. Both ends of the source wire are sealed to prevent leakage of radioactivity. The source wire is then inserted in a catheter for guiding the same to the treatment site. The modified section (=container) itself is rigid and is only flexibly linked to the remainder, unmodified portion of the source.

[00010] From US-A-5,683,345 an apparatus and a method are known which apparatus includes an elongated flexible catheter tube having proximal and distal end portions with a lumen extending therebetween. One or more treating elements or seeds containing radioactive material are positionable within the lumen and are movable between the proximal and distal end portions under the force of liquid flowing through the lumen. The radiation source used according this document consists of individual treating elements which may be joined together to form a train of treating elements by use of several length of high tempered spring wire to prevent the treating elements from becoming too spaced apart while moving through the catheter.

[00011] Other typical drawbacks encountered with prior art radiation sources and devices for delivering the same to the site to be treated are related to the duration of exposure, controllability of the radiation exposure (dosage, homogeneity of treatment), the necessity to conduct a "stepping treatment", or difficulties in retracting the radiation source from the catheter and therefore the risk of undesirable exposure of both the patient and any medical personal handling the treatment device. It is the object of the invention to overcome these and other drawbacks of prior art radiation sources.

SUMMARY OF THE INVENTION

[00012] These and other objects are achieved by the radiation source as defined in the appended claims. In a first aspect the invention relates to a radiation source for use in radiation treatment which comprises one or more and preferably at least two treating elements (seeds) comprising a radiation emitting element and means for containment of said radiation emitting element, which radiation source is characterized in that the seeds are sequentially, directly and movably linked to each other and/or to the transfer wire. Thereby the seeds form a flexible radiation source, preferably a flexible elongated radiation source.

[00013] The means for containment of said radiation emitting element can be a capsule, preferably comprising a metal. Preferably the seeds have an elongated shape. In a preferred embodiment the central axis of the radiation source essentially parallels the elongated axis of the seeds.

[00014] According to a preferred embodiment the seeds are linked by magnetic forces to each other and/or to the transfer wire.

[00015] According to another embodiment the seeds are mechanically linked to each other and/or the transfer wire. In a preferred embodiment the linkage is made mechanically and magnetically.

[00016] In one preferred embodiment of mechanical linkage the seeds comprise male and female means for coupling which female means for coupling receive the male means for coupling of the following or proceeding seed in the radiation source to form a flexible joint. Preferably the male and female means for coupling are on opposing sides of the seed, even more preferably they are opposed to each other at the longitudinal ends on the end caps of the seed.

[00017] According to another preferred embodiment at least two seeds are linked to another by way of a single flexible joining member extending throughout the entire length of the radiation source. Preferably such joining member is a string which extends through openings in the seeds.

[00018] In another aspect, the invention relates to an apparatus for vascular radiation treatment, comprising (1) an elongated catheter having a proximal end portion, a distal end portion and a lumen extending therebetween for receiving a radiation source, (2) optionally a guide wire in a separate, second lumen, and (3) a radiation source which comprises one or more, preferably at least two treating elements (seeds) comprising a radiation emitting element and means for containment of said radiation emitting element, wherein said seeds are sequentially, directly and movably attached to each other and/or the transfer wire.

[00019] Preferably the apparatus additionally comprises a x-ray fluoroscopy device for monitoring the radiation source. The apparatus may also comprise a containment vessel for storage of the radiation source and/or the individual seeds. In another embodiment the apparatus is an apparatus comprising a radiation source wherein the seeds are attached to each other by magnetic forces and the apparatus further comprises a magnetic means for guiding the radiation source.

[00020] In a third aspect, the invention relates to a method for vascular radiation treatment comprising the steps of

(a) directing an elongated catheter having a proximal end portion, a distal end portion and a lumen extending therebetween for receiving a radiation source, to the selected site to be treated preferably by way of a guide wire in a separate lumen,

(b) introducing a radiation source into the catheter at its proximal end portion, which radiation source comprises one or more, preferably at least two treating elements (seeds) comprising a radiation emitting element and means for containment of said radiation emitting element, wherein said seeds are sequentially, directly and movably attached to each other and/or the transfer wire to form a flexible radiation source which can be moved through said lumen of the catheter,

(c) moving said radiation source to said distal end portion preferably by use of a transfer wire,

(d) maintaining said radiation source at said distal end portion for a determined period of time, and

(e) retracting said radiation source to the proximal end portion preferably by way of a transfer wire.

[00021] Preferably a radiation source as defined above is used.

[00022] Preferably moving and/or retracting in steps (c) and/or (e) is achieved by pushing or pulling the radiation source.

[00023] According to a preferred embodiment, the seeds are linked to each other by magnetic forces and the transfer wire comprises a magnet to magnetically effect said pulling of the radiation source in steps (c) and/or (e). In an alternative embodiment, an external magnetic field may be applied to move the radiation source comprising seeds linked to each other by magnetic forces.

[00024] According to another embodiment the transfer wire may comprise a male or female means for coupling and a radiation source comprising such male and female means for coupling is linked to the transfer wire by engagement with the complementary means for coupling on the terminal seed thereof.

BRIEF DESCRIPTION OF DRAWINGS

[00025] In the following the invention will be explained in greater detail on the basis of the illustrated embodiment represented schematically in the figures. There is shown:

Fig. 1 shows schematically a radiation source of the invention comprising magnetic seeds; Fig. 1a to 1c showing various shapes of seeds to be employed.

Fig. 2a to 2c schematically show a radiation source of the invention comprising seeds with male and female means for coupling.

Fig. 3a and 3b schematically show a radiation source of the invention wherein the seeds are mechanically linked by a joining member.

Fig. 4 is a schematic view of the catheter of the apparatus according to the invention.

DETAILED DISCLOSURE OF THE INVENTION

[00026] In the following the invention will be described in detail referring to the attached drawings for illustration purposes. In these drawings like reference numerals refer to like parts. The term "radiation" is to be understood to relate to ionizing or radioactive radiation.

[00027] The radiation source for use in endovascular radiation treatment according to the invention comprises one or more, preferably at least two treating elements, so-called seeds. These seeds comprise a radiation emitting element or radiation emitting core and means for containment of said radiation emitting element. The radiation source of the invention is characterized in that said seeds are sequentially, directly and movably linked to each other and/or the transfer wire and thereby form a flexible radiation source of the desired length.

[00028] The expression "directly" relates to a linkage which is achieved by direct engagement of the seeds themselves. The invention does not encompass linkage of the seeds by holding them together by use of external devices, containers or other fixing structures. Rather, the linkage of the seeds is obtained by forces exerted by the seeds themselves such as magnetic forces and/or a mechanical engagement of the seeds with each other wherein the seeds themselves form an active part of the joint. The term "directly" encompasses embodiments where the seeds are linked to a common structure. The expression "directly" does not exclude spacing members inserted between the seeds interrupting the chain of seeds by being interdisposed between the same, such as empty

means for containment, non-radioactive magnetic particles, spheres and the like. A radiation source devoid of such spacing members is, however, preferred.

[00029] With the term "movably" as used herein, a linkage or joint between two seeds is meant which allows for any type of movement of the seeds relative to each other including rotational movement, bending or movement of one seed out of the axis of the central axis of the radiation source (the preceeding seeds still having their axis essentially parallel thereto), longitudinal movement of one seed away from the other without interruption or breaking the linkage, any type of vibration and so on, provided that the link between the seeds is not interrupted. The term "linked", "attached" and "joined" or the expression "linkage", "joined" and "coupling" are used interchangeably and refer to the interconnection between the seeds as defined above.

[00030] The radiation source of the present invention comprises one or more and preferably at least two treating elements or seeds. Typically the number of seeds comprised in this radiation source is chosen to cover the desired length of the vessel to be treated. Preferably the radiation source will cover a number of seeds sufficient to provide a radiation source of at least 2 mm in length, preferably 10 to 50 mm in length, more preferably 20 to 40 mm in length. With the term "sequentially" it is meant that the seeds are linked to each other to form a chain of seeds. This does not exclude embodiments, wherein multiple e.g. 2, 3, 4 etc. smaller seeds are arranged in parallel and are then linked sequentially, directly and movably to the following duplett, triplett, quadruplett and so on.

[00031] Typically the individual seeds will have a length in the range of 1.0 to 10.0 mm, more preferably 1.5 to 4 mm and most preferred 2 to 3 mm.

[00032] Preferably the seeds are of the elongated, more preferably cylindrical shape and have an outer diameter of the means of containment thereof in the range of between 0.2 and 1.0 mm, preferably between 0.3 and 0.8 mm. Preferably the seeds comprise rounded (rounded edges of a generally flat end cap) or spherical end caps on one or both ends thereof.

[00033] The means for containment typically is a capsule. This capsule may be elongated, and may be hollow cylinder or tube comprising a first and a second end plug, but may have any shape suitable for forming seeds such as spheres, ellipsoids, doughnuts, cones, flat-end-tubes, disks, cubes etc., provided it comprises a cavity for receiving and enclosing said radiation emitting element and does not impair or inhibit movement of the seed in the catheter lumen.

[00034] Preferably the means for containment is a metallic capsule which comprises a metal selected from the group comprising stainless steel, Ag, Pt, Ti, Ni, Fe, Mn, Cr, Nb, Co, Au or there alloys, including mixtures thereof. It may also comprise any other suitable casing coated with one of these metals. More preferably the means for containment comprises a hollow cylindrical body having rounded or spherical end caps in one or both ends thereof, which may also form the above first and second end plug. More preferably the means of containment comprises a permanent magnetic material, most preferably Ni, Fe, stainless steel, Mn, Co and the like. According to another embodiment, the means for containment may also comprise a magnetizable material which is later magnetized by applying an external magnetic field.

[00035] The means for containment may also be formed from glass or plastics material such acrylics e.g. by coating a solid radiation emitting element to obtain a tight coating layer, provided it prevents leakage of radioactivity in the lumen of the catheter. It may further comprise a coating e.g. of Teflon material or a similar low-friction material to reduce friction between the treating element or seed and the wall of the catheter lumen in which it moves.

[00036] The radiation emitting element comprised in said means for containment comprises any α-, β- and/or γ-emitting substance, preferably a pure β emitter and/or a β- and γ-emitting substance. Typically the radiation emitting element comprises one or more radioactive materials selected from the group comprising Cs^{137}, Co^{57}, Sr^{89}, Y^{90}, Au^{198}, Pd^{103}, Se^{75}, Sr^{90}, Ru^{106}, P^{32}, Ir^{192}, Re^{188}, W^{188} and I^{125} and other suitable nuclide(s).

[00037] The radioactive material may be contained in a solid such as metal, glass, foil or ceramics or in a free flowing form such as a powder or liquid or is dispersed in a fluid. Neither form nor state of the radioactive material is crucial, provided it allows for introducing the same in the means for containment and for secure containment.

[00038] The seeds are prepared by introducing the radiation emitting element into the means for containment made from the appropriate material and closing the same, e.g. by fixing the second end plug, e.g. by welding. The seeds may then be magnetized by applying an external magnetic field. Or the means for containment may be closed with appropriate end plugs having male and female coupling means.

[00039] The amount of radioactivity is typically in the range of 0.45 to 25,000 mCi per centimeter of vessel to be treated, depending on the radiation source used. The emitted radiation should be sufficient to deliver a desired dosage of from 100 to about 10,000 rads, preferably about 700 to 5,000 rads in a about 2 to 10 minutes to the tissue to be treated.

[00040] According to a preferred embodiment the radiation source is characterized in that the seeds are attached to each other by magnetic forces. According to this embodiment the seeds are held together by way of attracting magnetic forces e.g. forces exerted between the metallic capsules as means for containment of each seed. In this embodiment the means for containment is preferably made from a magnetic material such as Ni, Fe, Co, stainless steel, and Mn. According to another embodiment the means for containment may be made of a magnetizable material which is then magnetized by applying a magnetic field. The magnetic field can be applied immediately after production of the seeds or just before to use thereof. The magnetic field can be applied either by way of a permanent magnet or by an electromagnet.

[00041] In a preferred embodiment shown in Fig. 1 the magnetic seeds (1) are attached in north-south orientation. Thereby they form an elongated chain of seeds as the radiation source. More

preferably the seeds of this chain comprise a means for containment (2) having rounded (3a) or spherical (3b) end caps (3) on one or both ends to allow smooth bending characteristics and improved magnetic adhesion of the seeds during bending of the chain.

[00042] In Fig. 1b an embodiment is shown wherein the means of containments having rounded end caps (3a) are spaced apart by magnetic spheres (3c).

[00043] According to another embodiment of the radiation source according to the invention, the seeds are mechanically linked. Any suitable means for effecting said linkage may be used as long as it provides for longitudinal transmission of forces, exerted e.g. by pulling one seed to move the entire radiation source. The seeds may also be linked mechanically and magnetically to each other and/or the transfer wire.

[00044] One preferred mode of mechanical linkage are seeds comprising male and female means for coupling which female means for coupling receive the male means for coupling of the following or proceeding seed in the radiation source to form a flexible joint. Preferably said male and female means for coupling are located on opposite sides of the seed, even more preferably they are opposed to each other at the longitudinal ends on the end caps of the means for containment of the seed. Providing the means for coupling on the end caps bears the advantage that they can be produced separately, e.g. by use of a laser and are only thereafter contacted with the tube containing the radiation emitting element and fixed to the tube e.g. by laser or point welding.

[00045] The male means for coupling may extend from the means for containment and may comprise a head and optionally a spacing member, whereas the female means for coupling in this case comprises a receiving section for the head. Said receiving section of the female means for coupling is preferably complementary to at least the head of the male means for coupling but still allows for movement of the joint such as rotational movement or bending or deflection from the

central axis of the radiation source. Therefore the head of the male means for coupling preferably is in the form of a sphere.

[00046] In the preferred embodiment shown in Fig. 2a to 2c the male means for coupling (4a) comprises a spacing member (5) and a spherical head (6) and the receiving section of the female means for coupling (4b) is formed by extensions (7) of the means for containment (2), e.g. the capsule which extensions define a hollow space (8) having a recess (9) to receive the spacing member (5) when the head (6) of the male means for coupling is spaced in the hollow portion of said female means for coupling.

[00047] According to another embodiment of mechanical linkage, the male means for coupling is a hook and the female means for coupling is a second hook or a loop. In all cases both means for coupling may engage with each other or with a spacing member such as a ring, an empty means for containment or other member of a chain.

[00048] In case the coupling means and/or the containment means are made from a magnetic or magnetizable material, the seeds can be linked magnetically and mechanically.

[00049] According to another embodiment of mechanical linkage the one or more, preferably at least two seeds are linked to each other and/or to the transfer wire by way of a single flexible joining member extending throughout the length of the radiation source. As shown in Fig. 3a and 3b the joining member (10) preferably is a flexible string which extends through openings (11) in the seeds (1). Preferably these openings are central openings in each seed as shown in Fig. 3a, but may also comprise one or more lateral or circumferential openings of each seed (see Fig. 3b). The string is preferably made from a flexible material resistant to degradation by the emitted radiation. As an example nylon, acrylics, and metals such as Fe, Ti/Ni-alloys or aluminum alloys are mentioned. To prevent the seeds from being separated from each other they may be fixed on the joining member or the joining member may act as a means for holding them together.

[00050] All of the above linkages provide a chain of seeds or "train of treating elements" as a radiation source which allows for movement of said radiation source either by pushing or pulling at the terminal elements of the chain. The single seeds are linked to each other and preferably to the transfer wire with sufficient strength to allow such pulling movement without the radiation source being split up into its individual parts. On the other hand, the links between the seeds may be created or interrupted by the appropriate manipulation of each link. Thus, a radiation source of the desired length can be created and the length can be chosen appropriate for the intended use. At the same time the length of the source is not limited by its stiffness or rigidity due to the flexible joints. Thus, the radiation source of the invention allows for a one-step radiation treatment of elongated segments of a vessel.

[00051] Due to the movable link provided in the radiation source of the invention, this flexible radiation source can easily follow the bends and partitions of a blood vessel within the body to be treated. Apparently the radiation source of the invention is not limited to treatment of coronary restenosis, but may be used in any type of endovascular irradiation treatment e.g. in cancer therapy.

[00052] Due to direct engagement of the seeds with each other the source further allows for movement by pushing and pulling the chain of seeds. Thus, the source of the invention may be used in a catheter comprising only one central lumen for receiving the radiation source. Accordingly the seeds can be arranged in the central axis of the vessel to be treated to allow for uniform and homogenous irradiation of the surrounding tissue. This has to be considered an important aspect as radiation intensity decreases strongly with distance from the radiation source and an out of center location of the radiation source will result in unpredictable and non-controllable inhomogenities in the radiation field created therefrom. Thus, with an out of center arrangement of the radiation source inhomogeneous radiation of the surrounding tissue results. This is overcome by use of the present radiation source.

[00053] According to the present invention, there is further provided an apparatus for endovascular radiation treatment comprising (1) an elongated catheter having a proximal end portion, a distal end portion and a lumen extending therebetween for receiving a radiation source, (2) optionally a guide wire in a separate lumen and (3) a radiation source as disclosed above.

[00054] Referring to Fig. 4 the apparatus of the invention makes use of a catheter (12) which is typically made from nylon material, although other plastic or rubber material may be used as well. The outer diameter of the catheter is sized according to the intended application, e.g. 5 mm or smaller for use in treating the stenotic site of a coronary artery. The inner diameter of the lumen (14) extending between the distal end portion (13a) and the proximal end portion (13b) of the catheter is correspondingly sized to receive the treating elements or seeds (1) and is typically in the range of from about 0.2 to about 1.5 mm. Thus, to direct the flexible radiation source the internal diameter of the catheter is such that it permits movement of the seeds and helps to direct the radiation source. The catheter may have a coating, e.g. of Teflon or other suitable material to reduce friction upon movement of the radiation source. Likewise the catheter may be filled with a suitable liquid such as sterile water, PBS etc.

[00055] The catheter may not have sufficient strength or torsional rigidity for insertion along a lengthy serpentine vascular path and may then require use of a guide wire which ist then arranged in a separate lumen. Typically angioplasty procedures result in a distance between the percutaneous entryport and the coronary artery of approximately 90 to 120 cm, the length of the catheter corresponding thereto.

[00056] To assist in positioning the distal end portion (13a) of the catheter (12) at the desired location or site to be treated, the catheter may be advanced over a guide wire (15) that is preinserted to the desired location in the manner well known in the art. The guide wire is one commonly used in prior art and can be made from any suitable type of metal, preferably memory-resistant metals, i.e. materials that can accept up to a 1 % strain with less than a 1 % permanent alteration in its original configuration. Preferred materials include nickel-titanium alloys such as Nitinol or

aluminum alloys such as Tinal alloy BB. In the apparatus of the invention, a separate wire is used for moving said radiation source which is the so-called transfer wire. This transfer wire can be made from the same materials as the guide wire and is preferably mechanically and/or magnetically linked to the radiation source. The guide wire is used for directing the catheter only.

[00057] The apparatus of the invention may further comprise a containment vessel for a storage of the radiation source and/or the individual seeds and for shielding the patient to be treated and the medical personal from exposure to irradiation during introduction and retraction of the catheter. The containment vessel preferably is in flow communication with the catheter, although it can be constructed as a separate or separable part to allow for separate storage and/or disposal.

[00058] The apparatus of the invention may further comprise a x-ray fluoroscopy device for monitoring the radiation source as, for example, described in US-A-5,833,593. This allows for exact positioning of the radiation source and, thus, for precise control of the treatment site.

[00059] Finally, the apparatus of the invention may comprise a magnetic means for guiding or moving the radiation source, in case the radiation source is created from magnetic seeds.

[00060] In a third aspect there is provided a method for vascular radiation treatment comprising the steps of

(a) directing an elongated catheter having a proximal end portion, a distal end portion and a lumen extending therebetween for receiving a radiation source, to the selected site to be treated preferably by way of a guide wire in a separate lumen,

(b) introducing a radiation source into the catheter at its proximal end portion, which radiation source comprises one or more, preferably at least two treating elements (seeds) comprising a radiation emitting element and means for containment of said radiation emitting element, wherein said seeds are sequentially, directly and movably attached to each other and/or to the transfer wire, and which can be moved through said lumen of the catheter,

(c) moving said radiation source to said distal end portion preferably by way of a transfer wire,

(d) maintaining said radiation source at said distal end for a determined period of time, and

(e) retracting said radiation source to the proximal end portion preferably by way of a transfer wire.

[00061] Preferably the radiation sources disclosed above are used in the method of the invention.

[00062] The steps of moving and/or retracting (c) and/or (e) can be achieved by pushing or pulling the radiation source.

[00063] More in detail, according to one preferred embodiment, movement in step (c) is achieved by pushing and said movement or retracting in step (e) is achieved by pulling said radiation source. For doing so, the radiation source may be linked to a transfer wire at its proximal end. In this embodiment the radiation source is introduced in the catheter lumen at its proximal end and pushed by use of the transfer wire to its distal end. After the predetermined treatment time, the radiation source is retracted by pulling out the transfer wire from the catheter. Alternatively, the radiation source may be engaged with the transfer wire at its distal end and may be pulled by said guide wire to the distal end of the catheter and pushed back to the proximal end portion during retracting of the source.

[00064] In case of a radiation source comprising magnetic seeds, movement of said radiation source in steps (c) and/or (e) may be achieved by applying an external magnetic field. Alternatively in this case the transfer wire may comprise a magnet to magnetically push or pull the radiation source in step (c) and/or (e). In the preferred embodiment the transfer wire itself is magnetic.

[00065] In case of the seeds being linked to each other by male and female means for coupling, the transfer wire may comprise a male or female means for coupling and the radiation source may be linked to the transfer wire at its distal or proximal end through the complementary means for coupling on the terminal seed thereof.

[00066] Separate wires are used for moving said radiation source (transfer wire) and for directing the catheter (guide wire).

[00067] Due to the use of a catheter having a single lumen for receiving the radiation source only, the inner diameter of said lumen can be increased as compared to catheters comprising several of such lumens. Accordingly, larger seeds may be used. This allows for including higher radiation dosages in each single seed. Use of a single lumen further allows for a central arrangement of the catheter and thus of the radiation source within the vessel. Thereby uniform and homogeneous irradiation of the surrounding tissue is achieved. Due to the seeds being directly linked to each other and due to flexible linkage, no gaps in the irradiated field occur and thus the radiation source needs not be moved during treatment i.e. no "stepping treatment" is required to obtain the homogeneous radiation over the entire segment of the vessel to be treated. This further improves control of the treatment.

[00068] Although being described with respect to the preferred embodiments above, this description is not to be considered limited thereto and the skilled worker will appreciate the possibility of several variations of the invention as defined in the appending claims without deviating from its scope.